Combating drought and desertification: Pioneering contributions of Russia and the Soviet Union

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Introduction

Throughout human history, virtually all societies have developed distinctive perceptions and cultural responses to droughts and deserts. Because these events directly threatened their livelihoods and food security. At its most basic, drought is associated with dry conditions and deserts with sands and dry winds. The Russian empire was one of the few places in the world, where early efforts to combat droughts and desertification originated in the nineteenth century. In imperial Russia, droughts were frequent and often devastating. They used to cause massive crop failure and famine . Russia's grain bowl was exposed to the sultry breath of the desert, in the form of dry winds and droughts. They often penetrated into Russia and affected the Central Black Earth region, especially the Rostov and Stavropol steppes, southern Ukraine, the northern regions of Crimea, the Volga region, and the Urals. In the 17th century, Russia experienced 34 dry years, and in the 19th century, 40; on average, there was one dry year for 3-4 normal years.

In his essays "The Power of the Land," Gleb Uspensky showed how terribly dependent the Russian peasant was on the mercy of nature in imperial Russia: "Right now, from my window, I see the ground, poorly covered with snow, thin green grass, an inch thin, and on this thin blade of grass, completely dependent is a big man with a beard, with sharp legs. A blade of grass can grow, or it can perish, the earth can be a mother or a wicked stepmother—what will happen, absolutely no one knows. It will be as the earth wishes; it will be as the earth makes it and as it is able to make it... And so this man is in the complete power of this slender blade of grass. After all, only in a year, almost to the day, will it bring a loaf of bread to the peasant's table, but it may not—it itself is at the mercy of every cloud, every breeze, every ray of sunshine"..[1].

A terrible crop failure and famine engulfed the Volga region in 1873. The great Russian writer Lev Tolstoy wrote about it:[2] "Having traveled through the villages from my place (from my farm on the Tananyk River) to Buzuluk, 70 miles, and in the other direction from me to Borsk, 70 miles... and passing through the villages, I, who have always lived in the village and know the conditions of rural life intimately, was horrified by what I saw: bare fields where wheat, oats, millet, barley, and flax had been sown, so that it was impossible to tell what had been sown. And this in mid-July! The roads were filled with people either going to Ufa Province or looking for work, which either doesn't exist at all, or the pay is so low that the worker can't earn enough to cover what they eat at home".

Drought (засуха) and dry winds (суховеи) for Russia's peasant classes were synonymous for crop failures (неурожаи) and famines (голод). In the memory of Russian people droughts and dry winds were the constant companions of hunger and poverty. Droughts and dry winds frequently devastating crop fields. Often, the consequences were so dire that the peasants en masse left the villages in search of "good land" or opportunities of working for a livelihood.

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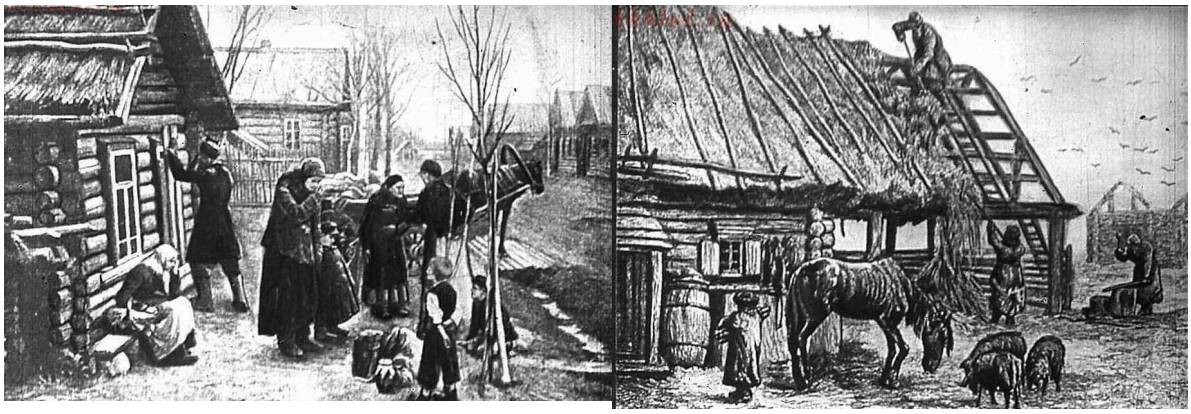
[1] Г. У с п е н с к и й . Полн. собр. соч., т. 8, Изд. АН СССР, 1949, стр. 27—28.
[2] Л. Т о л с т ой, Полн. собр. соч., т. 17 ГИХЛ, 1936, стр. 62



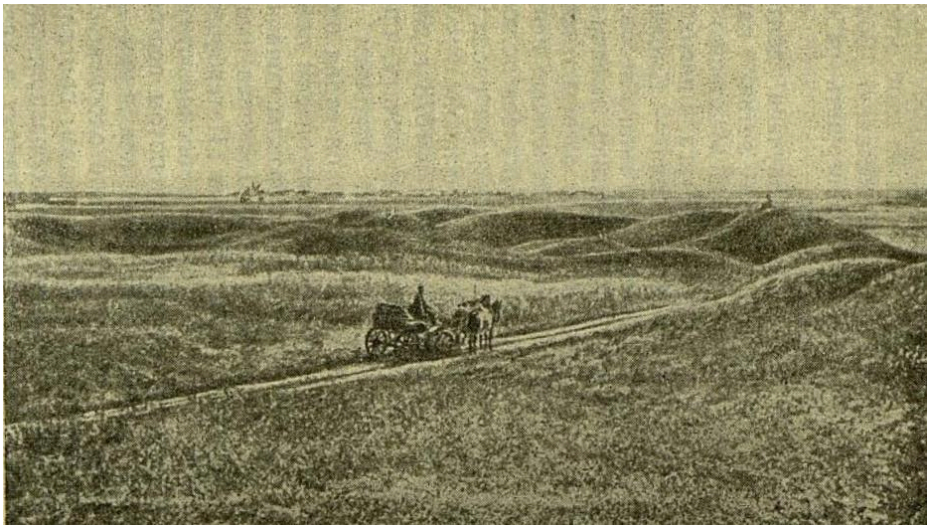
In Russia's steppe and forest-steppe regions[3], concerns about droughts and dry winds existed side by side with persistent efforts to combat encroachment of drifting sands onto fertile agricultural lands. To communicate the seriousness of this threat, people in Russia preferred the terms – пески наступают (sands are attacking) or наступление песков (invasion of sands). In the perception of most people, drought, dry wind, and sand movement (deserts) existed as closely connected natural hazards.

Beginning of systematic efforts to combat droughts

Early efforts to combat droughts in the Russian steppes can be traced to the work of the great scientist Vasily Vasilievich Dokuchaev, widely recognized as the father of modern soil science. In 1891, a catastrophic drought occurred that enveloped almost the entire Black Earth region, triggering an unprecedented crop failure, famine, and loss of life. In the wake of this famine in January 1892, scientist V. V. Dokuchaev gave a series of public lectures. He donated the proceeds from these lectures to the starving people. These lectures were compiled in his famous book "Our Steppes: Then and Now (Наши степи: прежде и теперь)", which was published in 1892.

In his work ", V.V. Dokuchaev set himself the task, first and foremost, of "diagnosing the disease". It was about identification of the causes of the drought. For this purpose, he needed to analyze the changes in the steppes from their origin to their present state. He begins with a study of the latest developments in the geology of Russia in general and the southern steppes in particular in Chapter 1 , then examines the surface structure and water of Steppes in Chapter 2. In chapter 3, Dokuchaev provides a detailed analytical overview of the soils of the steppe. He explores vegetation of the Steppe in Chapter 4, Steppe Fauna in Chapter 5, Steppe Climate in Chapter 6. Finally in Chapter 7, V.V Dokuchaev outlines methods of organizing water management in the Russian Steppe. A snapshot of Russian steppe is shown below:

[3] A steppe is a vast, dry, and mostly treeless grassland. It is a "semi-arid" ecosystem, meaning it gets more rain than a desert but not enough to support a forest.
A forest steppe is a transitional zone where temperate forests and open grasslands meet and interlock. It acts as an ecological boundary between the humid, tree-heavy regions of the north and the dry, wide-open grasslands of the south



In this work Dokuchaev outlined his "landscape principle." It was essentially a methodology, and also a general concept for an ecologically sustainable landscape approach to organizing and managing agriculture and nature management. V.V. Dokuchaev convincingly demonstrated that the disaster the peasantry recurrently confronted "didn't strike yesterday."He argued that it was a natural and inexorable consequence of poor agricultural practices in the steppe and forest-steppe regions of Russia. Massive deforestation and intensive plowing of lands without regard for the terrain and soil characteristics triggered the progressive degradation of steppe and forest-steppe landscapes. It was reflected in soil erosion, growth of ravines, the shallowing of many rivers, the silting of water sources, and, as a consequence, the inevitable drying out and depletion of the lands.

Having diagnosed the illness of the "core of agriculture," V.V. Dokuchaev saw the path to its recovery in a set of carefully considered measures. These were aimed at combating not the droughts and crop failures themselves, but the underlying causes. Among the most important of these, he considered those that could increase the water supply to the steppes, alleviate the continental climate, and restore the conditions that existed there "previously" but were thoughtlessly destroyed "now." V.V. Dokuchaev developed a large-scale programme of specific and scientifically based measures for soil conservation, drought control, crop farming, and agricultural stabilization in the black soil zone. In this programme, he laid the general foundations of a modern adaptive landscape approach and scientific optimization of agricultural landscapes.

V.V. Dokuchaev proposed scientific organization of the territory, taking into account its landscape morphogenetic structure; development and widespread implementation of anti-erosion measures; creation of a system of ponds and reservoirs; widespread forest plantation; development of selection and genetics, adaptive seed production, and livestock farming. Given the comprehensive nature of this plan, its "cornerstone" was the protection and improvement of soils. It was seen as a mirror of the landscape and the foundation of adaptive landscape agriculture. This approach became the theoretical basis for the activities of a future endeavour. It was the Special Expedition that the Forestry Department of the Ministry of Agriculture and State Property of Russia fielded in 1893.

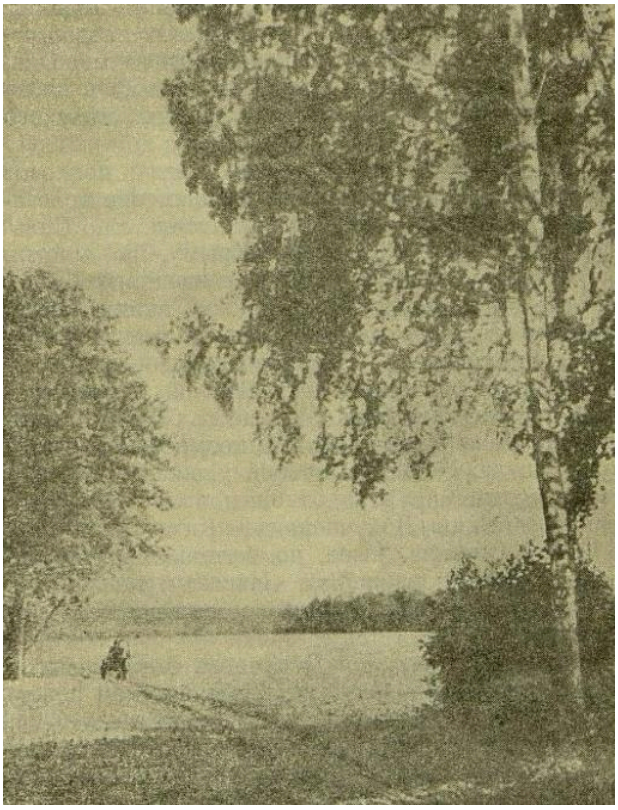
Its formal name was "Special Expedition for Testing and Evaluating Various Methods and Techniques of Forestry and Water Management in the Russian Steppe (Особая экспедиция по испытанию и учёту различных способов и приёмов лесного и водного хозяйства в степях России)". The expedition was led by V.V. Dokuchaev. The goal was to improve conditions for agricultural land use and streamline water management in the Russian steppe zone through afforestation and water supply measures. The core of the practical work undertaken was to be the irrigation of the steppes and the rational use of accumulated moisture. It required a systematic study of the natural connections in the "land-forest-water" triangle and practical testing of various methods[4].

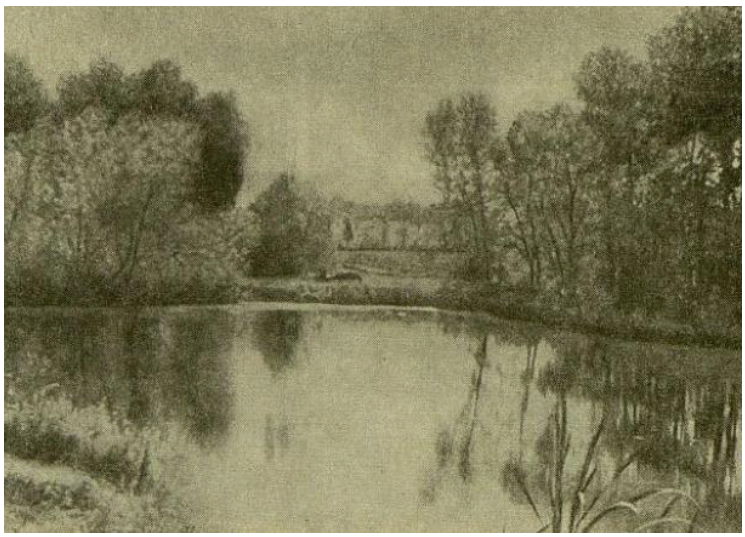
Based on the recommendations of the expedition, three experimental sites were established in the steppe of the Central Blackearth zone. One of the test sites was the "Kamennaya Steppe" (Stone Steppe) in the Voronezh Governorate. This experimental site was converted into the V.V. Dokuchaev Kamenno-stepnaya Agricultural Experimental Station on 16 June 1911. At the beginning it had three departments – soil science, meteorology, and plant production to which a forestry department was added in 1920. The experimental station was allocated 1,323 ha of land where the famous system of forest belts was laid out. The first 140 hectares of protective forest plantations were created between 1894 and 1908. The basic principles of their establishment were defined by V.V. Dokuchaev as follows: .

“ Protective strips span across the open steppes, although not continuous plantings. Then come snow-collecting edges, hedges, plantings on the slopes of ravines and around steppe wells, etc.

[4] Воронежская Энциклопедия: Особая экспедиция Лесного департамента, https://vrnency.ru/vol-1/ve-1-o/a-00091-o

Ribbon-shaped plantings planted across the steppe should serve to protect crops from winds, storms, and dry winds, regulate snow cover and accumulate snowdrifts and river banks in appropriate places, and stabilize the slopes of ravines." V.V. Dokuchaev particularly emphasized that "... the general course of the expedition's work should be aimed at establishing the most correct possible balance between water, forest, meadow, and other economic lands in the selected areas." In the photos below, forest strips and one of the ponds established by V.V. Dokuchaev in the Kamennaya steppe, 1946 photo.





In 1946, The Kamenno-stepnaya Agricultural Experimental Station was reorganized into V.V. Dokuchaev Agricultural Institute in the Central Blackearth Zone (Институт земледелия Центрально-Чернозёмной полосы имени В. В. Докучаева). After the fall of the Soviet Union, the institute underwent a series of organizational restructuring and modernization of facilities. In 2019, the institute was renamed as V.V. Dokuchaev Voronezh Federal Agrarian Scientific Centre.

The effectiveness of field-protecting (shelterbelt) afforestation has been convincingly demonstrated by 130 years of experience of planting and growing forests in Kamennaya Steppe. This experience has allowed for a thorough and comprehensive study of the impact of shelterbelt afforestation on microclimate, water management, soil fertility, and crop yields[5]

[5] Виктор Турусов и Елена Коновалова, Воронежский Федеральный Аграрный Научный Центр им. В.В. Докучаева, Докучаевские бастионы в действии. К 75-летию Государственного плана преобразования природы,

Even in the early stage, forest belts help to retain and accumulate snow in fields, reliably protect field crops in the zone of their influence (25-30 times the height of the forest belt) from dry winds, dust storms, frosts and other extreme environmental factors. It is known that increased wind speed during dry periods leads to increased moisture evaporation from the soil surface increasing unproductive water loss by plants. By reducing wind speed, forest belts significantly reduce unproductive water loss. Under the canopy of forest belts and in the fields protected by them, after just 25-30 years, the soii-water properties of chernozems are significantly improved. Biogenic soil-forming processes are also enhanced. Here, the reserves of nutrients removed from the arable layer with the harvest are restored faster than in open fields. It helps maintain the high potential level of fertility of black soils.

Moisture is crucial for achieving sustainable harvests. But the picture here is contradictory. On the one hand, there is a struggle to retain soil moisture, while on the other, 10-20 billion cubic meters of water are lost as surface runoff in areas experiencing spring floods. At the same time, the most valuable top soil is washed away, linear erosion processes develop, and soil fertility is sharply reduced. If it were possible to retain at least half of this water in the fields, then it would have been possible to obtain an additional 8.2 million tons of grain. In the open steppe, water rolls off deeply frozen soil like asphalt. But in the fields between the strips, the soil thaws earlier and absorbs snow water like a sponge. Observations have shown that in steppes unprotected by forests, 50 to 75% of meltwater leaves the soil surface uselessly. With forest coverage of up to 6% of watersheds, water runoff is reduced by more than half.

The enormous water-regulating role of forest belts is explained by the high infiltration capacity of the soils beneath the forest. Forest soils have a coarse-grained structure and are covered by a thick layer of loose litter. Therefore, it easily and quickly absorbs both melt and rainwater, transporting them further into underground storage facilities, which increases the groundwater level, thus affecting the root zone of plants. But the situation was completely different on treeless slopes, where meltwater flows down ravines and gullies into rivers, and only a small portion of it replenishes groundwater reserves. Forest belts and gully plantings are a reliable means of combating soil erosion.

By retaining and reducing the runoff of meltwater and rainwater, forests help prevent soil degradation and the formation of new gullies and ravines. Forest belts also play an invaluable role in the biological treatment of runoff water. Forest belts 15-20 meters wide near ravines almost completely remove ammonia, increase the alkalinity of runoff water, and reduce its hardness. Water that has passed through the forest litter has significantly improved bacteriological quality.

Thus, many years of experience in the Kamennaya Steppe allowed scientists to draw four main conclusions about the effect of forest plantations as “moisture stores”. Firstly, they reduce the amount of water uselessly flowing from fields and transform surface runoff into underground runoff; secondly, they replenish groundwater reserves and raise their level in comparison with the steppe; thirdly, they increase

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https://vrnikc.ru/news/dokuchaevskie-bastiony-v-dejstvii-k-75-letiyu-gosudarstvennogo-plana-preobrazovaniya-prirody/

the supply of rivers, lakes and ponds with groundwater; fourthly, they reduce and even stop erosion processes, protecting rivers, lakes and ponds from shallowing and pollution.

The unprecedented drought of 1946, which destroyed crops across most of the steppe zone of the USSR, was a severe test and trial of the validity of the environmental protection concepts that the scientists developed over the years. In that year, the fields of Kamennaya Steppe yielded 16.5 centners (1.65 t/ha) of winter wheat, 15 centners (1.5 t/ha) of winter rye, 10.6 centners (1.06) of spring wheat, 15.8 centners (1.58 t/ha) of oats, and 21.2 centners (2.12 t/ha) of sunflower per hectare. In neighboring collective farms located in the open steppe yields of these crops were three to four times less.

The negative impact of the drought was significantly reduced thanks to the grassland farming system combined with the Dokuchaev agroforestry reclamation complex consisting of forest shelterbelts. A modern view of the Dokuchaev Kamenno-Stepnaya Experimental Station, now the Voronez Voronezh Federal Agrarian Scientific Centre, is shown above:

Combatting desertification

Toward the end of the nineteenth century, sandy areas in Astrakhan's semi-desert faced a natural disaster. As a result of irregular land use, bare sands formed in place of sandy areas, burying pastures, arable lands and villages. To combat this phenomenon, the Russian Government formed the Astrakhan sand fixing organization which started functioning in 1904. It was probably one of the first institutional attempts to combat an environmental hazard which would later be defined as desertification. Sowing grasses became the main technique for anchoring (fixing) sands.

Following the droughts in 1921 and 1924, the Soviet Government took the decision to conduct research-cum-field testing work to combat drought in the Astrakhan semi-desert areas. For this purpose,

the Bogdinski Base Station (Богдинский опорный пункт) was established in 1924 headed by eminent forestry scientist Mitrophan Alekseevich Orlov (pictured below).

At the end of 1924, Orlov selected a plot of 440 ha for planting field-protective (shelterbelt) forests. The first planting of forest strips began in the spring of 1925. In this way, in the semi-desert area near the salt lake Baskunchak, forest shelterbelts were established in such harsh conditions – for the first time in world practice. A view of the salt lake is shown below.

The main tasks of the Bogdinski Base Station were: 1) to prove the possibility of establishing forest shelterbelts on brown weakly solonetz subsandy soils[6] in semi-desert areas; 2) conduct trials on growing woody and shrub tree species on these soils. Over the first six years 1924–1930, experimental-cum-field trials of shelterbelt plantations with different tree species composition were established on 170 hectares of land with brown soils . Multiyear trials at the Bogdinski Base Station proved for the first time the possibility of establishing protective forest plantations in semi-arid areas (shown below).

The first years of work brought successful results. In the afforested areas shielded by forest strips, wind velocity decreased, snow accumulation began, grass vegetation increased in height and density, but importantly richer than before in moisture-loving plant species. Aridity started slowly receding in areas covered by forest plantations.

The next stage of establishing forest shelterbelt plantations began with the adoption of the Grand Plan for Transformation of Nature by the Soviet Government on 20 October 1948. To support implementation of the plan with research data, the Bogdinski Support Base was upgraded into Bogdinski scientific agroforestry reclamation experimental station (Богдинская научно-исследовательская агролесомелиоративная опытная станция). The Russian acronym of this famous institute was НИАГЛОС (NIAGLOS). As the implementation of the grand plan began, the Saratov-Astrakhan stretch of the state shelterbelt forest plantation was established on the territory of the Astrakhan region over the period 1950–1953. As of 1953, forest strips were established on 230 hectares of land owned by Bogdinski NIAGLOS. These protective plantations became the main base for conducting agroforestry

[6] Brown weakly solonetz subsandy soils are characterized by a light top layer, a dense, hard, salt-affected B-horizon that restricts root growth, and a sandy-loam to loamy-sand texture. They commonly occur in semi-arid plains. Managing them effectively requires addressing their low water-holding capacity and high sodium content.

research and trial works. In the early 1960s, institutional capacity of NIAGLOS was expanded by allocation of 5,000 ha of land and creation of five substations at different locations.

Many specialists viewed that it wasn't possible to grow forest plantations in areas that receive less than 400 mm of annual precipitation. But forty years of research work at the Bogdo substation of the research centre where annual rainfall didn't always amount to even 200 mm refuted this view. It demonstrated the possibility of establishing shelterbelt plantations in harsh semi-arid regions. Data obtained from multi-year research and trials in nurseries and at Bogdinski NIAGLOS, showed the possibility of growing shelterbelt forests and their important practical role in combating drought and dust storms. Researchers developed specific types of protective forest plantations for growing on pastures. They also developed different methods for anchoring shifting sands and key aspects of growing protective forest plantations along embankments and on saline floodplain soils[7].

Protective forest belts at the age of 30 years in a leafy state reduced velocity of wind by 33 percent, wind power by 55 percent. In the spring, forest belts increased temperatures by 0.4 to 0.6 degree C. In the zone shielded by the forest belts, relative humidity of air increased by 2.6–4.0 percent and evaporation from the water surface decreased by 28–34.0 percent[8].

Droughts in the context of the US "Dust Bowl" (1930–1940): How Dokuchaev's science influenced US Government's policy making in agriculture

While in imperial Russia, concerns about drought, and sands encroaching onto agricultural lands as significant threats to food production and rural livelihoods arose toward the end of the nineteenth century, they entered global agricultural and environmental thinking later. They became truly mainstream in international agricultural development only in the 1970s and 1980s.

In the United States, the "Dust Bowl " of the 1930s played a decisive role in creating such concerns. Dry land farming on the Great Plains (which were almost similar to Russia's steppes known as Prairie) led to the systematic destruction of the prairie grasses. In the ranching regions, overgrazing also destroyed large areas of grassland. Gradually, the land was laid bare, and significant environmental damage began to occur. Among the natural elements, the strong winds of the region were particularly devastating.

With the onset of drought in 1930, the overfarmed and overgrazed land began to blow away. Winds whipped across the plains, raising billowing clouds of dust. The sky could darken for days, and even well-sealed homes could have a thick layer of dust on the furniture. In some places, the dust drifted like snow, covering farm buildings and houses. Nineteen states in the heartland of the United States became a vast dust bowl. With no chance of making a living, farm families abandoned their homes and land,

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[7] Н.Н. Дрыгина. Пески наступают: из истории защитного лесонасаждения в Астраханской областиhttps://cyberleninka.ru/article/n/peski-nastupayut-iz-istorii-zaschitnogo-lesonasazhdeniya-v-astrahanskoy-oblasti/viewer

[8] Асмачкин А.П., Лепеско В.В., Терюков А.Г. Состояние и перспективы защитного лесоразведения в Астраханской области. Волгоград, 1989, С.50.

fleeing westward to become migrant laborers. The results of such a dust storm in the Cimarron County, Oklahoma are shown below[9].

By triggering a massive agricultural collapse and unprecedented internal migration, the “Dust Bowl” significantly worsened and prolonged America’s Great Depression. In finding a solution to this crisis, America’s New Deal policymakers used Dokuchaev’s scientific principles as a framework for policy response. [10] Before Dokuchaev’s ideas penetrated the US scientific community, the U.S. Bureau of Soils operated under the doctrine that soil was an "indestructible, immutable asset" that could never be exhausted. When massive dust storms devastated the Great Plains, this old paradigm collapsed. Policymakers used Dokuchaev's genetic and ecological soil science to guide the nation's emergency response through several channels[11].

The chief architect of a “Russian revolution” in US government soil science was Curtis Marbut, who headed the US Soil Survey from 1910 until 1934. Marbut became convinced by Russian science after reading a book by Russian scientist Konstantin Glinka published in German in 1914. Marbut tested the Russian approach in the Great Plains. He worked hard to persuade workers in the US Soil Survey of the need to change the methodology. Marbut had succeeded by the late 1920s. He was assisted by two Russian emigrant soil scientists, Jacob Joffe and Constantine Nikiforoff. Links between American and Soviet soil scientists were cemented at two scientific Congresses, in the United States and the Soviet

[9]https://www.loc.gov/classroom-materials/united-states-history-primary-source-timeline/great-depression-and-world-war-ii-1929-1945/dust-bowl/

[10] David Moon. 2020. The American Steppes - The Unexpected Russian Roots of Great Plains Agriculture, 1870s–1930s , pp. 188 - 225, available at https://www.cambridge.org/core/books/abs/american-steppes/soil-science-

[11] Nicole Xiang. The Soil Conservation Service: Debate and Diplomacy in the Dust Bowl, Senior Division Historical Paper, https://nhd.org/wp-content/uploads/2023/02/Paper-Project-Example-2-Soil-Conservation-Service.pdf

Union, in 1927 and 1930. By the 1930s, US soil maps designated the soils of the Great Plains "Chernozems," using the Russian term (Black Earth), using Dokuchaev's exact Russian terminology. Because they used Dokuchaev's maps, American scientists instantly recognized that the Great Plains were ecologically identical to the Russian steppes—meaning Russia's past climate disasters were a direct blueprint for America's present crisis (The American Steppe, Soil Science II, Chapter 6).

Vasily V. Dokuchaev highlighted this similarity in his book "Our Steppes: Then and Now". In the first chapter titled "The Last Little Page in the geology of Russia in general and the southern steppes in particular", he wrote
"Our Russian black earth steppes, by the nature of the climate, relief and flora, and also, probably, by fauna, and partly by land and soils, are an inseparable part of that great steppe belt, which almost completely covers the northern hemisphere and which includes the Spanish deserts, the Hungarian and Danube deserts, the European- Russian and Siberian-Asian steppes, and, finally, the American United States. (наши русские черноземные степи, по характеру климата, рельефу и флоре, а также, вероятно, по фауне, а отчасти по грунтам и почвам, являются неразрывной частью того великого степного пояса, который почти сплошь одевает северное полушарие и в состав которого входят испанские десьертосы, венгерские и придунайские пусты, европейско-русские и сибирско-азиатские степи, и, наконец, Американских Соединенных Штатов.)

Hugh Hammond Bennett, the "father of soil conservation" and architect of the New Deal's response to the Dust Bowl, used this newly revolutionized American soil science to shape federal policy. As the first director of the Soil Conservation Service (SCS), Bennett rejected the old view that soil was just dead dirt to be plowed relentlessly. Influenced by the Russian concept of soil as a dynamic, living body, Bennett convinced Congress that soil erosion was a systemic, ecological disease requiring agronomic solutions rather than just engineering fixes. Under Bennett, the SCS treated entire watersheds as unified, living systems—applying Dokuchaev's macro-zonal thinking to target the specific environmental vulnerabilities of Chernozem soils.[12]

The most visible, direct policy replication of Dokuchaev's work was President Franklin D. Roosevelt's Prairie States Forestry Project (1935) (The Great Plains Shelterbelt). Looking for a way to stop wind erosion and protect vulnerable topsoil, federal foresters and soil scientists explicitly drew upon Dokuchaev's famous 1892 steppe expedition blueprints[13]. The U.S. government paid workers to plant over 220 million trees, creating a 100-mile-wide network of windbreaks stretching from Canada down to

[12] Surviving the Dust Bowl (Article) The Father of Soil Conservationhttps://www.pbs.org/wgbh/americanexperience/features/surviving-the-dust-bowl-biography-hugh-hammond-bennett/

[13] Moon, David; Agnoletti, M., ed. (2005) The Dokuchaev expedition to the Steppes and sustainability in the 1890s. In: Third International Conference of the European Society for Environmental History, 2005-02-16 - 2005-02-19. https://strathprints.strath.ac.uk/1618/

Texas. Just as Dokuchaev proved in Russia, these shelterbelts altered the localized microclimate of the Plains, breaking the wind, trapping winter snow, and anchoring the volatile soil[14].

Dokuchaev's science dictated that soil cannot be managed by political borders, but by natural soil zones and watersheds. In 1937, the Roosevelt administration leveraged this concept to establish Soil Conservation Districts across the country. This policy transferred the power of soil management out of local municipal boundaries and placed it into locally run districts organized entirely by natural ecological and hydrological boundaries, ensuring that anti-desertification efforts conformed to the laws of the soil itself[15].

Agroforestry as a formal concept in the context of drought and desertification: How Dokuchaev's ideas shaped its emergence?

Planting trees in association with crops and livestock is an ancient practice. But its transition into a formal global science-based land use approach occurred gradually as a result of specific institutional movements. The term agroforestry was coined in 1977 as part of the early international efforts to initiate research on integrated production systems involving crops and trees.[16]

But long before modern science coined "agroforestry," the foundations of agroforestry were laid at the end of the 19th century by Vasily Vasilyevich Dokuchaev, along with fellow scientists Alexander Ivanovich Voeikov and Grigory Nikolaevich Vysotsky. [17] [18] through their pioneering concept of " agrolesomelioration (агролесомелиорация)." This Russian term consists of three elements - agro (агро) meaning agriculture, Les (лес) meaning forest and amelioration (мелиорация) meaning improvement. It thus translates to improvement through a combination of agriculture and forestry. The desired improvement was supposed to come from a specifically designed combination of crops, trees and soil moisture conservation.

The main theoretical principles of agroforestry amelioration were[19]:

- Planting forests in the steppe along watersheds, passes and open spaces in the form of strips and bands of varying widths to protect agricultural crops from unfavorable climate conditions (protective forest belts, snow-collecting edges on plains and gentle slopes, hedges of shrubs and

[14] Marc Elie. Cold Warriors in the Soil Sciences: The Soviet-US Conflict on Soil Classification, 1950s–1970s. Centaurus, 2024, 66 (3), pp.387-412. ⟨10.1484/J.CNT.5.150566⟩. ⟨hal-05544634⟩
[15] History of the Soil and Water Conservation District, https://www.blackhawkswcd.org/history
[16] Nair, P.K.R., Kumar, B.M., Nair, V.D. (2021). Definition and Concepts of Agroforestry. In: An Introduction to Agroforestry. Springer, Cham. https://doi.org/10.1007/978-3-030-75358-0_2
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trees, moisture-collecting plantings), which should occupy from 15 to 18 percent of the total steppe area;
- Forest planting in areas unsuitable for economic use (afforestation of sands, light sandy loams, rocky and saline areas;
- Plantations in dry and waterlogged gullies;
- Work to strengthen active ravines, chalk outcrops and river banks with forest vegetation;
- Cultivation of fruit trees and shrubs in the steppes.

Today, Vasily Dokuchaev's principles of agroforestry amelioration and Stalin's Great Plan for the Transformation of Nature (1948–1965) form the backbone of several modern agroforestry approaches:

Tree shelterbelts for sustainable agroforestry: The core concept is to reduce wind speed designed with explicit spatial and vertical density tiers. The goal is to increase the growth and yield of various field and horticultural crops. The concept incorporates Dokuchaev's scientific principles of microclimate modification, snow retention and soil moisture conservation. The design of these shelterbelts heavily borrows ideas from the design of the large state forest shelterbelts of the Great Plan for Transformation of Nature – multi-tiered consisting of tree, shrub species with specific spatial designs to reduce wind speed, aerodynamic lifting of the wind thus reducing evaporation from the soil surface and conserving soil moisture.[20] [21]

Alley Cropping for productive and sustainable land use : The core concept is cultivating food crops between wide, permanent rows of deep-rooted woody perennials. The goal is to create productive and sustainable land use practices. The concept incorporates Dokuchaev's principle of looking at soils as a living organism and managing the "organism" factor of soil formation to accelerate nutrient cycling and counter drought. The deep roots act as "safety nets" to capture deep groundwater. They pull nutrients upward via desuction, altering the soil profile just as Dokuchaev observed in the Russian Chernozem zones. As part of the organism "factor" perennial vegetation plays an outsized influence on the development of fertile functioning soils, as perennials stabilize soils in place and help build soil organic matter as well as structural components such as aggregates and macropores[22].[23] [24]

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[24] Trofimov, I.A., Trofimova, L.S., Yakovleva, E.P. (2021). The Work of V.V. Dokuchaev in the Chernozem Zone of Russia: A Contribution to Productive and Sustainable Agrolandscapes, and a Basis for Recent Research. In: Mueller, L., Sychev, V.G., Dronin, N.M., Eulenstein, F. (eds) Exploring and Optimizing Agricultural Landscapes. Innovations in Landscape Research. Springer, Cham. https://doi.org/10.1007/978-3-030-67448-9_5

Riparian Forest Buffers: The core concept is establishing multi-species strips of trees, shrubs, and perennial grasses along streams and rivers. It directly adapts Dokuchaev's principle of Agroforestry amelioration as stated above "Planting forests in the steppe along watersheds, passes and open spaces in the form of strips and bands of varying widths to protect agricultural crops from unfavorable climate conditions (protective forest belts, snow-collecting edges on plains and gentle slopes, hedges of shrubs and trees, moisture-collecting plantings), Work to strengthen active ravines, chalk outcrops and river banks with forest vegetation. The aim is to control macro-landscape erosion and check the desiccation of a regional water basin[25].

Emergence of the Concept of Desertification

Following the "Dust Bowl" and the creation of the U.S. Soil Conservation Service, concern was still largely framed as soil erosion control, not yet as "desertification." The concept of desertification emerged during colonial rule in West Africa out of concerns about signs of desiccation and the creeping of the Sahara desert into the Sahel. The actual term 'desertification' is credited to Aubreville (1949), who used it to describe the change of productive land into desert as a result of man's activity in the tropical forest zone of Africa[26]. During the severe Sahel droughts of the late 1960s and early 1970s, the issue attracted global attention. Millions of people were affected by crop failures and livestock losses across the Sahel region of Africa. The concept "desertification" entered the mainstream concern of international agricultural development in 1977 with the United Nations holding a Conference on Desertification in Nairobi in 1977.

This conference elevated desertification to a major international development issue. It linked land degradation to food security and encouraged governments to incorporate anti-desertification measures into agricultural planning. In the early 1990s, the concept of desertification entered the broader framework of sustainable development. This culminated in the adoption of the United Nations Convention to Combat Desertification in 1994 (UNCCD), which remains the principal international agreement addressing desertification and land degradation.

Global approaches to combating desertification: How the research and testing results obtained at Astrakhan-based NIAGLOS contributed to these efforts?

The works of the Bogdinski scientific agroforestry reclamation experimental station (Богдинская научно-исследовательская агролесомелиоративная опытная станция), abbreviated as NIAGLOS in Russian, revolutionized global efforts to combat desertification by pioneering large-scale

[25] Jennifer Marston. A mini guide to agroforestry: what is it & how can it improve ag and fight climate change? November 9 2022,
https://agfundernews.com/guide-to-agroforestry-what-it-is-how-it-can-improve-ag-and-fight-climate-change

[26] Hermann S.M. and Hutchinson C.F. The changing contexts of the desertification debate. Journal of Arid Environments. Volume 63, Issue 3, November 2005, Pages 538-555.

protective afforestation, mechanical sand stabilization techniques, and the cultivation of highly resilient arid plant species. The main contributions were:

Blueprint for multi-tiered "Green Walls": NIAGLOS played a vital foundational role in designing and testing the massive shelterbelts built during the Soviet Union's "Great Plan for the Transformation of Nature". The methods perfected at the NIAGLOS station proved that strategically planted belts of trees and shrubs could alter localized microclimates, block wind erosion, and stop sand dunes from encroaching onto vital agricultural zones. It provided a direct engineering blueprint for the world's most massive modern re-greening initiatives, including the "Great Green Wall of China (Three-North Shelterbelt Program) and" the African Union's Great Green Wall"[27] [28].

Identification of specialized flora for arid zones

Researchers at NIAGLOS evaluated and selected specific combinations of drought-resistant and salt-tolerant plant varieties that could thrive in nutrient-void, hyper-arid environments. These included the following species:[29] [30] [31]

Trees and shrubs

Black saxaul (*Haloxylon salicornicum*) — one of the key species for desert and semi-desert regions. It was studied in detail; for instance, it was found that root pruning in the nursery is beneficial—it stimulates the development of a fibrous root system and significantly improves the survival and growth of saxaul on pastures.

Leafless calligonum (*Calligonum aphyllum)* — a shrub actively used for sand stabilization.

Grey winterfat (*Krascheninnikovia ceratoides*) — another shrub that demonstrated good land-reclamation properties. Together with the shrub *Calligonum aphyllum*, it was used in the formation of multi-layered plant communities on the study plots.

Russian olive (*Elaeagnus angustifolia)* — a tree or shrub used in phytoreclamation.

Tamarisk – It was valued for its ability to grow on saline soils and solonetz: as a crinohalophyte, it establishes and develops well when planted as seedlings, although it is less palatable to livestock.

Grasses and other herbaceous plants:

Kochia (*Kochia prostrata*) — a valuable pasture plant to stabilize sands and restore the ecosystem.

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[27] Great Green Wall (China), https://en.wikipedia.org/wiki/GreaþGreen=Wall=(China)

[28] Andrew Bilski.2018. Africa's Great Green Wall: A work in progress - Making ambition reality, https://thinklandscape.globallandscapesforum.org/28687/africas-great-green-wall-a-work-in-progress

[29] Л. П. Рыбашлыкова , С. Ю. Турко. Трансформация фитоценозов в пустынно-пастбищных экосистемах (на примере северо-западного Прикаспия) Растительные ресурсы, 2023, Т. 59, № 1, стр. 93-106.

[30] A. Babaev and N. Kharin. Combating desertification in the USSR. https://www.fao.org/4/u5200e/u5200e0a.htm

[31] Болаев Б.К. Киштанов Б. В. УСТОЙЧИВОСТЬ ЛЕСОПАСТБИЩ В СОВРЕМЕННЫХ УСЛОВИЯХ ИЗМЕНЕНИЯ КЛИМАТ, https://cyberleninka.ru/article/n/ustoychivost-lesopastbisch-v-sovremennyh-usloviyah-izmeneniya-klimata

Crested wheatgrass (*Agropyron cristatum*) — a perennial grass effective for sand stabilization.
Sand ryegrass (*Leymus racemosus*) — initially used in plantings to stabilize the surface before introducing tree and shrub species:

Pioneering combined biological-mechanical methods for sand fixation

Creation of protective forest belts: NIAGLOS researchers planted trees and shrubs (such as tamarisk, saxaul, and Calligonum). Their extensive root systems physically bound the sand together, while their crowns and trunks created a windbreak. These belts were planted in strips perpendicular to the direction of sand movement.

Phytoamelioration: NIAGLOS researchers actively developed phytoamelioration (the use of vegetation to improve, reclaim, and restore degraded soils and environments) as the key biological method for sand fixation. They selected and tested plant species—including trees, shrubs, and grasses—capable of effectively stabilizing shifting sands. Once established, the vegetation continued to stabilize the soil.

Combined approaches: Before trees could take root in active shifting sands, the sand had to be physically immobilized. NIAGLOS advanced early mechanical sand fixation methods, using intricate grid structures made of locally sourced reeds and clay coverings to trap moisture and anchor the sand. Mechanical barriers (such as special netting or screens) were installed at key points to halt sand movement immediately, while biological land reclamation was initiated within these zones. [32] [33] [34]

Approaches and methods used for sand fixation and halting desertification in UNCCD-supported programmes and projects

The projects supported by UNCCD deploy a combination of physical, biological, and socio-economic approaches to fix shifting sand dunes and achieve Land Degradation Neutrality (LDN). These interventions scale from localized mechanical stabilization to massive regional frameworks.[35] [36]

Mechanical & Engineering Approaches
These immediate, non-living interventions temporarily halt sand movement so vegetation can safely take root.

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[32] Дрыгина Н. Н. Пески наступают: из истории защитного лесонасаждения в Астраханской области, https://sciup.org/peski-nastupajutiz-istorii-zashhitnogo-lesonasazhdenija-v-astrahanskoj-oblasti-
[33] Как Калмыкия превратилась в пустыню, https://ria.ru/20191003/1559373512.html
[34] https://t.me/kalmyckij_uzel/1821
[35] Convention to Combat Desertification, Committee for the Review of the Implementation of the Convention; Twenty-third session; Implementation of the voluntary land degradation neutrality targets and related implementation efforts. Panama City, Panama, 1–5 December 2025, https://www.unccd.int/sites/default/files/2025-10/2514578E.pdf
[36] https://www.unccd.int/dune-fixationstabilization

Straw Checkerboards: Workers bury wheat or rice straw in 1x1 meter square grid patterns. This decreases ground-level wind speeds, creates microclimates, and retains surface moisture.[37]
Artificial Sand Fences: Barriers made of palm fronds, brushwood, or plastic mesh are built 1 to 1.5 meters high. They are placed perpendicular to prevailing winds to form artificial, stable "stop dunes".[38]
Surface Mulching: Moving sand is covered with crop residues, clay-water mixtures, or environmentally safe chemical binders to form a hard crust.
Photovoltaic Sand Fixation: Solar panels are constructed over moving dunes. They generate electricity while directly shielding the soil to reduce wind erosion.

Biological & Ecological Approaches
Long-term stabilization relies on using drought-resistant, local living organisms to permanently anchor the soil.
Drought-Resistant Afforestation: Planting hardy, deep-rooted pioneer species like *Saxaul* (*Haloxylon ammodendron*), *Tamarix*, desert willows, and *Acacia*. Their roots bind the loose sand matrices.
Agroforestry Systems: Integrating multi-purpose trees with crops to create windbreaks. These systems reduce soil erosion while simultaneously yielding food and fodder for communities.
Induced Biocrusts: Spraying cyanobacteria or specialized bio-cementing formulas onto sand surfaces. This accelerates the development of natural biological soil crusts.

Socio-Economic & Policy Approaches
Technical fixes fail without local community buy-in and regional coordination. [

Participatory Bottom-Up Planning: Incorporating indigenous knowledge into National Action Programmes (NAPs). Local populations are integrated directly into the project design and maintenance phases.

Enclosure & Exclusion Zones: Securing fragile, newly treated sand dunes by strictly prohibiting livestock grazing and human transit.

Land Tenure Reform: Working alongside organizations like the Food and Agriculture Organization (FAO) to guarantee land rights. Securing tenure incentivizes long-term community investments in land restoration.

How the results and methods developed by NIAGLOS researchers are incorporated in the UNCCD-supported programmes and projects?

Many of the biological sand-fixation, halting desertification and dryland restoration methods now funded through UNCCD programmes build on ideas and often directly adapt the research and field

[37] Algae and grapes are China's new weapons against desertification, https://news.cgtn.com/news/3d3d514f35497a4d7a457a6333566d54/index.html
[38] Dune fixation: a tool for desertification control, https://www.fao.org/4/x5309e/x5309e06.htm

practices developed at the Astrakhan-based NIAGLOS from the mid-twentieth century onward. Because of cold war rivalry these contributions are seldom explicitly acknowledged in international policy documents. But they form part of the broader scientific foundation of modern desertification control.

If we closely analyze the approaches and methods used in UNCCD-supported projects, described in the paragraph above, we see that “Straw Checkerboards” method is a direct adaptation of the NIAGLOS-developed mechanical method using intricate grid structures made of locally sourced reeds and clay coverings to trap moisture and anchor the sand. “Artificial Sand Fences” closely parallel NIAGLOS-developed mechanical barriers installed at key points to immobilize the sand in place. Similarly, UNCCD’s “Drought-Resistant Afforestation” and “Agroforestry Systems” include many of the tree/shrub species, which were drought resistant and salt-tolerant and could thrive in nutrient-void, hyper-arid environments, selected by NIAGLOS researchers for sand afforestation.

Conclusion

As elsewhere in the world, frequent crop failures resulting in food shortages and famines were recurrent events in the Russian empire. For the Russian peasantry, the most dreaded factors causing massive crop failures were drought (засуха), dry wind (суховей) and encroachment of sands onto agricultural lands and human settlements (наступление песков). Systematic efforts to combat drought, dry wind and shifting sands began in Russia in the late nineteenth century much earlier than when these issues became mainstream in Western countries and international agricultural development thinking. In the wake of the devastating famine in 1891 that engulfed the entire central black earth zone of Russia, the Russian Government took a momentous decision to find out the root causes of recurrent droughts and address those causes. In 1892, the Forestry Department commissioned a "Special Expedition for Testing and Evaluating Various Methods and Techniques of Forestry and Water Management in the Russian Steppe”. The expedition was headed by Vasily Vasilievich Dokuchaev, the great scientist, widely recognized as the father of modern soil science.

Following the famine, V.V. Dokuchaev gave a series of public lectures, the proceeds from which he donated to the victims of the famine. Later he compiled those lectures in a book titled “Our Steppes: Then and Now (Наши степи: прежде и теперь), which was published in 1892. By employing a “before” and “after” approach, Vasily Dokuchaev presented a vivid picture of the ecological conditions – the state of land, soil, water availability, natural vegetation, fauna, and their complex interaction – that existed before on the Russian Steppe in the Central Black Earth zone of the country. He then presented a list of missteps that were allowed to occur in exploitation of the Steppe for agricultural production and other non-food uses that turned the once highly productive steppe into a barren degraded land with vastly different ecology. Based on this comparison, V.V. Dokuchaev recommended a list of measures to cure the underlying causes of drought and start its ecological restoration. It became the theoretical foundation of organizing the work of the Special Expedition

In this book, we have described in detail the landscape approach that Dokuchaev outlined for organizing and managing agriculture and nature management. We have highlighted the key aspects of the programme activities conducted at Kamenno-stepnaya experimental station centered on planting field-protective forest strips, control of soil erosion, restoration of national soil fertility, soil-moisture

conservation, and prudent water management. We have discussed the activities of another organization for controlling the advance of shifting sands, what would later come to be known as “desertification”. It was the Astrakhan-based Scientific agroforestry amelioration research experimental station, widely known by its Russian acronym NIAGLOS.

We have shown how V.V. Dokuchavev’s science and the experimental -cum–field testing research data contributed to global efforts to combat drought and desertification in the modern era.